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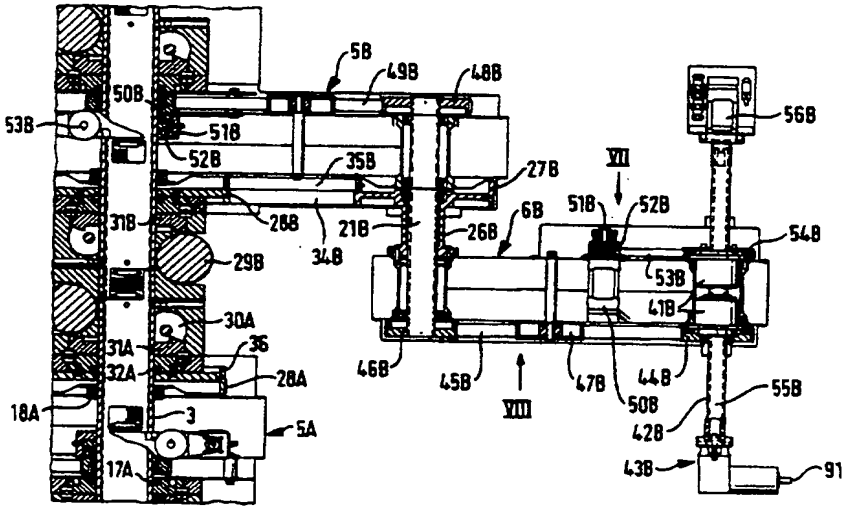

(57) Abstract

A robotic device for gathering and/or operating on objects such as fish, from a supply area and releasing the objects in a delivery area has a rigid tubular column (3) on which one end of each of two inner arms (5A, 5B) is mounted for unlimited rotation by motors (11A, B) and spiroid gearboxes (13, 14). Outer arms (6A, 6B) are pivotably mounted on the respective inner arms and carry pulleys (27) connected by steel belts (35) to further pulleys (28) rotatably mounted on the column (3) and driven by further motors (29) and spiroid gearboxes (30, 31) fixed to the column (3). Power supplies and control signals for the motors (11, 29) are delivered *via* the interior of the column (3). The outer end of each outer arm carries a working head (43) which can be moved vertically and turned in response to output signals from optical sensors which also control the motors (11, 29).

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TRANSFER OR ROBOTIC DEVICE

The present invention relates to transfer and robotic devices.

According to the invention there is provided a transfer or robotic device for gathering and/or operating on successive objects from a supply area and releasing the said objects in a delivery area, comprising a support structure and an arm assembly, the arm assembly comprising an inner arm mounted at an inner end thereof on a support structure, driving means for unlimitedly rotating the inner arm around a fixed axis of the support structure, an outer arm pivotally mounted on the outer end of the inner arm for pivotal movement relative to the inner arm about an axis parallel to the said fixed axis, means for angularly swinging the outer arm relatively to the inner arm and means on the outer end of the outer arm for selectively engaging and releasing each said object.

Such a device by moving continuously in one direction of rotation can operate with lower energy comsumption and stress than a comparable device which oscillates over a limited angular range.

Advantageously, driving means for the inner arm and for the swinging means for the outer arm are stationarily mounted on the supported structure, the driving motor for swinging the outer arm being connected to the outer arm by a transmission extending along the inner arm.

The invention will now be further described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a perspective view of a transfer device according to the invention;

Figure 2 is a vertical axial section through a central portion of the device;

Figure 3 is a vertical section, including part of Figure 2, through the upper arm structure;

Figures 4 and 5 are views of inner arm pulley systems in the direction of the arrows IV an V in Figure 2;

Figure 6 is a perspective view of a spiroid worm and wormgear pair;

Figures 7 and 8 are views of outer arm pulley systems seen in the direction of the arrows VII and VIII of Figure 3;

Figure 9 is a vertical section through the slip ring and rotary joint assembly at the top of the device;

Figure 10 is a diagrammatic plan view of an installation incorporating the device;

Figure 11 is a view of one of the two working heads partly in section;

Figure 12 is a plan view on the line XII-XII of Figure 11 with some parts removed;

Figure 13 is a section on the line XIII-XIII of Figure 12; and

Figure 14 shows diagrammatically in vertical section an alternative driving system.

As shown in Figure 1, the transfer device has a pedestal 1 with a bottom flange 2 by means of which it is securely anchored to a floor by means of a ring of anchor bolts (not shown). The pedestal carried two articulated arm assemblies A and B. The arms A and B are essentially identical with the exception that apart from the elements carried at their outer ends, the arm A is inverted in relation to the arm B. In the following description, where it is necessary to identify a component of a particular arm, the letter A or B will be added to the specific reference numeral.

Within the outer casing of the pedestal 1 extends a central vertical tube 3 (of external diameter 100 mm) forming a central column the lowermost end of which is secured to the base flange 2 with appropriate stiffening members 4.

Each arm assembly has an inner arm 5 and an outer arm 6. Each of the arms 5,6 is fabricated from sheet metal. The lower inner arm 5A is rotatably supported by means of a hub 7A which in

turn is supported through a crossed-roller bearing 8A on a gear box casing 9A fixed to the central tube 3 by screws 10.

The lower arm 5A is driven in rotation about the axis of the central tube 3 by a brushless direct current motor 11A which drives through a toothed belt reduction transmission a worm gear shaft 13 meshing with a spiroid gear 14 secured to the hub 7A. Power supply and control signals for the motor 11A are supplied by cables extending within the tube 3 to power and data connections 15A,16A.

The lower inner arm 5A is further supported radially on the central tube 3 by lower and upper ball bearings 17A,18A.

Near the outer end of the lower inner arm 5A, a vertical shaft 21A is rotatably supported in lower and upper bearings 22A,23A in the inner lower arm 5A and projects upwards to support rotatably the inner end of the lower outer arm 6A on further ball bearings 24A,25A. The lower outer arm 6A has a downwardly extending tubular sleeve 26A which houses the bearing 24A within a pulley portion 27A.

A second pulley 28A is rotatably supported on the central tube 3 by a bearing 32A and is secured to a spiroid worm wheel 31A meshing with a spiroid worm 30A driven by a motor 29A, the arrangement being similar to that for rotating the inner lower arm 5A around the tube 3. The pulleys 27A and 28A have upper and lower cylindrical surfaces around which are wrapped end portions of upper and lower flexible steel bands 34A,35A by appropriate fasteners 36. This arrangement enables backlash to be eliminated. The motor 29A is carried by the gearbox housing 37A for the spiroid gearing 30A,31A and is secured to the tube 3 by further screws 10.

The tube 3 is extended further upwards either in one piece or, as shown in the drawing, by a separate portion 3B which is rigidly connected to the tube 3. The tube portion 3B has secured to it the gearbox housing 9B carrying the driving motor 11B and spiroid gearing 13B,14B for rotating the inner upper arm 5B around

the tube 3B.

Mounted on the central tube extension 3B below the inner upper arm 5B is the motor 29B and gearbox housing 32B for driving the pulley 28B connected by bands 34B,35B to the pulley 27B connected by sleeve 26B to the casing forming the upper outer arm 6B.

Mounted near the outer end of each outer arm 6 is the housing 41 of a ball screw assembly 42 for raising an lowering an operating assembly 43. In this embodiment, the axis of each shaft 21 is equidistant from the axes of the column 3 and the ball screw 42.

The angular position of the working head 43 (yaw) relative to the outer arm 6 is determined by a toothed pulley 44 engaged by a toothed belt 45 which in turn passes round a toothed pulley 46 on the end of the shaft 21 and tensioned by an adjustable idler pulley 47 bearing against the outer surface of the belt 45. On the opposite end of the shaft 21 is mounted a further toothed pulley 48 engaged with a further toothed belt 49 passing round a toothed pulley 50 rotatably mounted by ball bearings on the tube 3 or 3B and within a gearbox housing 51 secured to the central tube 3 or 3B and containing a worm wheel 52 attached to the pulley 50 and meshing with a worm shaft 53 driven by a brushless DC motor 54 through a toothed belt reduction transmission 55.

Upward and downward movement of the working heads 43 is effected by means of ball screws 42, the nuts of which are appropriately rotated by a brushless DC motor 50, the shaft 51 of which carries a toothed pulley 52 engaged with a toothed belt 53 passing round a toothed pulley 54 on the nut of the ball screw mechanism.

The ball screw 42B is hollow and through it extends a drive shaft 55B for transmitting drive to the working head 43B from a further brushless DC electric motor 56B mounted on the opposite end of the ball screw 42B to the working head 43B.

To supply power to the electric motors 51 and 56, while

permitting the arms to rotate continuously around the tube 3,3B, a slip ring assembly 60 is mounted on the upper end of the tube portion 3B. Where the working heads 43 require a supply of compressed air, the slip ring assembly 60 includes a rotary joint. As shown in Figure 9, the slip ring assembly 60 has a tubular hub portion 61 which fits into the upper end of the tube 3B and is secured by four screws 62. The lower end of the hub portion 61 forms an anchorage for a protective lining 63 on the interior of the tubes 3 and 3B. The hub 61 is extended upwards by a thick-wall tube 64 of reduced diameter which is in turn extended upwards by a thin walled tube 65 carrying a set of brass slip rings 66 mounted in an insulating body 67 within which are incorporated leads connecting the slip rings 66 to respective terminals 68. A rotary sleeve 70 is supported on the exterior of the thick walled hub portion 64 by a pair of ball bearings 71. Between the two bearings 71, the inner wall of the sleeve 70 is formed with three grooves, the outer two of which contain rotary seals engaging the exterior of the hub portion 64. The middle groove 72 is connected to a compressed air outlet fitting 73 and registers with an outlet 74 from an axially extending bore 75 leading from a compressed air inlet fitting 76 receiving compressed air from a tube 77 extending upwards in the interior of the tubes 3,3B.

A rotary disc 78 is bolted to a flange 79 at the upper end of the rotary sleeve 70 and carries brush gear 80 which includes a separate resiliently biased arm 81 for each slip ring 66, each arm 81 terminating in a carbon brush in sliding contact with its respective slip ring 66.

The rotary disc 78 is secured to casing members 82,83 which in turn are secured to the casing of the upper inner arm 5B.

Although it would be possible to provide sufficient slip rings 66 to power the electric motors carried by the arm structures where the number of such motors is small, it is preferred to use the slip ring assembly 66,80 as a means of transferring electrical power from the stationary part of the

apparatus into the rotating part. Controlled distribution of this power to the various motors is then effected by mounting appropriate transputers on the upper surface of the casing 83 in the space around the slip ring assembly within a topmost casing 84. Control signals for the transputers can then be supplied by optic fibre extending upwards within the central tube 3,3B to a rotating interface (not shown) on the axis of the apparatus. Where sensor output signals from sensors carried by the working heads are to be fed back to the external control system (not shown) this can be effected by using a different frequency (i.e. a different wavelength of light) to that used for transmitting control signals to the transputers. Where the working heads require controlled intermittent supplies of compressed air, this can be effected by means of solenoid operated valves mounted within the casing 84, receiving their supply from the fitting 73 and suitably controlled by control boards within the casing 84 responsive to relevant signals supplied by the optical fibre link.

By way of example, a specific application of the apparatus will now be described. Referring to Figure 10, fish to be processed in a machine 91 are supplied with random spacing, position and orientation on an input conveyor 92. Each working head terminates in a gripper mechanism (not shown) which has to be correctly oriented and positioned and to move at the same speed as the fish to engage the fish by the head and to convey it to the processor 91 to which it must present the fish in its correct orientation and attitude. Figure 10 shows diagrammatically, in full lines the positions taken by the inner and outer arms 5 and 6 and the working head 43 when collecting a fish from the far side of the input conveyor 92 while the broken lines show the corresponding positions when collecting a fish from the near side of the input conveyor 92. It will be noted that the gripper at the end of the working head 43 moves in a straight line and at a constant speed while collecting a fish from the conveyor and also moves in a straight line and at a slower speed when delivering the

fish to the input 93 of the processor 91.

The position attitude and orientation of each successive fish is determined by optical means which do not form part of the present invention. This information is supplied to the control means (not shown) which determine the movements required of the inner and outer arms and the working heads and thus determine the controls applied to the driving motors 11, 29, 50, 54 and 56 as well as actuators in the working head now to be described.

The working head 43 includes a bevel gear mechanism which connects the central quill shaft 55 to an output shaft 91 carrying a housing 92 (figure 11) of a three position actuator assembly 93. The housing 92 is further supported on the housing of the bevel gear assembly by a ball bearing 94.

The gripper device for engaging and gripping the heads of the fish is mounted on a shaft 95 which can be turned through a range of 180° by a pneumatic actuator 96 comprising a substantially semi circular housing 97 containing a vane 98 with a seal 99 at its tip whereby the vane 98 and shaft 95 can be turned in one direction or the other by the admission of compressed air through inlets 100 or 101 under the control of respective solenoid operated valves in a valve block 102 having a compressed air inlet 103.

The shaft 95 can be locked in any of three positions by a cam plate 104 which can be moved away from or toward the shaft 95 by a linear pneumatic actuator 106. The cam plate 104 has two convexly curved cam surfaces 107 on either side of a re-entrant 108. When the actuator 106 is actuated to move the cam plate towards the shaft 95, the latter engages a roller 109 rotatably mounted on an arm 110 on the shaft 95 and thereby turns the shaft to the nearest of the three predetermined positions for the shaft. In the two end positions, one of which is shown in figure 11 and the other in figure 12, the gripper carried by the shaft 95 is in the correct orientation in relation to the next fish on the conveyor in accordance with which side of the fish is in contact with the conveyor. During transfer of the fish from the conveyor,

the actuator 106 moves the cam plate away from the shaft 95 and the rotary actuator 96 is operated to turn the shaft 95 towards the central of the three positions, the actuator 106 then being re-actuated to move the cam plate 104 towards the shaft 95 to cam the roller 109 into the re-entrant 108 thereby assisting the rotary actuator 96 in turning the shaft 95 and thereafter precisely locating and locking the shaft in the central position in which the fish carried by the gripper will be correctly presented to the processing machine 91 (figure 10).

To cushion the shock as the actuator 106 approaches the end of its stroke, each end of the cam plate 104 carries a roller 111 which engages a respective dash pot 112.

The compressed air supply hose for the inlet 103 together with control signal cables for the solenoid valve block 102 extends through the annular space between the quill shaft 55 and the ball screw assembly 42 in the interior of the latter to the opposite end of the ball screw where they are bundled together with the supply leads for the motor 56 to form a flexible bundle 113 leading into the casing 84 to the appropriate supply connections. Similarly, supply cables 114, with suitable stiffening, lead from the casing 84 to the outer arms 6.

To enable the entire apparatus to be kept clean by washing, all of the motors mounted on the central column tube 3,3B are enclosed within stainless steel sheet metal covers 115 and 116. Similarly, the driving transmissions on the inner and outer arms are covered by stainless steel sheet metal covers 117 and 118. Other portions which undergo relative movement are protected by appropriate rubber bellows 119,120 and 121.

The apparatus described above may have a total height of the order of 2 metres and be capable of handling payloads, such as fish, of say 6 kg. As a safety measure, it may be necessary to incorporate quick acting brakes, for example on the input shaft of each of the gearboxes.

A particular advantage of the continued rotation of the arm

structures in one direction is the saving of energy as compared with conventional robot arrangements where the operating arm structures oscillate over a limited angular range.

While the major driving motors in the embodiment described above are mounted on the central column tube 3,3B, the motors 50 and 56 are mounted on the arm structures themselves, requiring slip ring connections within the casing 84. Figure 14 shows diagrammatically an alternative arrangement for one of the arm assemblies, parts which correspond to those of the previous embodiment being indicated by the corresponding numeral increased by 200. With this arrangement, instead of mounting the motor 50 within the outer arm 206, the nut for the lead screw 242, the lead screw is connected by toothed belt and pulley drive 253 to an additional sleeve 350 in the articulation between the outer and inner arm portions 206,205 and a further toothed belt transmission 351 to a sleeve 352 surrounding the central column 203. The sleeve 352 is in turn driven through a toothed belt reduction transmission 354 by a motor 353 mounted on the tubular column 203.

The quill shaft 55 is replaced by inner and outer concentric shafts 357,358 which carry respective spur gears 359 and 360 at their upper ends meshing with pinions 361,362 on separate splined shafts 363,364 slidably engaged in toothed pulleys 365,366 carried in the outer arm 253 and connected to respective fixed driving motors 365 and 366 mounted on the central tubular column 203 with the interposition of toothed belt transmissions driving coaxial sleeves 367,368 at the articulation between the inner and outer arm sections 205,206. The lower ends of the two shafts 357,358 carry bevel gears 369,370 which both mesh with a bevel gear 371 on a shaft 372 supported in an output housing 373 and connected to an output shaft 374 in the latter by a toothed belt transmission 375. With such an arrangement, if both shafts 357 and 358 are driven at the same speed and in the same direction, the housing 373 will rotate about their common axis. If they are driven at the same speed in opposite directions, the housing remains stationary at

the output shaft 374 is rotated. Combinations of these two motions can accordingly be achieved by appropriate control of the motors 365,366.

Claims

1. A transfer or robotic device for gathering and/or operating on successive objects from a supply area and releasing the said objects in a delivery area, under the control of object-sensing means, comprising a support structure and an arm assembly, the arm assembly comprising an inner arm mounted at an inner end thereof on a support structure, driving means for unlimitedly rotating the inner arm around a fixed axis of the support structure, an outer arm pivotally mounted on the outer end of the inner arm for pivotal movement relative to the inner arm about an axis parallel to the said fixed axis, means for angularly swinging the outer arm relatively to the inner arm and means on the outer end of the outer arm for selectively engaging and releasing each said object, driving motor means for the inner arm and for the swinging means for the outer arm being stationarily mounted on the support structure, the driving motor means for swinging the outer arm being connected to the outer arm by a transmission extending along the inner arm.

2. A device according to claim 1, wherein the support structure comprises a tubular column on which the inner arm is rotatably mounted, and the driving motor means for the inner and outer arms each include a gear wheel surrounding the column and secured respectively to the inner arm and the transmission for the outer arm, power supply paths for the driving means extending within the column.

3. A device according to claim 2, wherein each gear wheel is the output member of a spiroid gearset of the respective driving motor means.

4. A device according to claim 2 or 3, wherein the driving motor means for the inner arm and the outer arm transmission are

substantially identical.

5. A device according to claim 4, wherein the two said drive means are mounted on the column on opposite sides of the inner arm.

6. A device according to any preceding claim, wherein a working head carried by the outer end of the outer arm is mounted for angular movement about an axis under the control of working head driving means stationarily mounted on the support structure, the working head being connected to its driving means by an inner transmission in the inner arm, a transfer element coaxial with the pivotal axis between the inner and outer arms and an outer transmission in the outer arm.

7. A device according to any preceding claim, wherein a supply path for electrical power for apparatus carried by the outer arm extends via flexible cable from a set of slip rings carried by the support structure coaxially with the axis of rotation of the inner arm.

8. A device according to claim 7, wherein the electrical power supply is continuous and a channel for control signals for controlling actuators carried by the outer arm and/or workhead extends through a rotary interface coaxial with the axis of rotation of the inner arm.

9. A device according to claim 8, wherein the said channel is optical.

10. A device according to any of the preceding claims, wherein a supply path for fluid under pressure for operating apparatus carried by the outer arm extends through a sealed rotary joint coaxial with the axis of rotation of the inner arm.

11. A device according to claim 10, wherein the fluid-pressure operated apparatus is pneumatic.

12. A device according to claim 11, wherein the apparatus includes a vane-type actuator for turning a tool about an axis.

13. A device according to claim 12, including a further actuator for selectively operating and releasing a locking member for locking the tool in its adjusted position about the said axis thereof.

14. A device according to claim 13, wherein the locking member has cam surfaces for turning the tool into the nearest of the plurality of predetermined positions.

15. A device according to any of claims 12 to 14, wherein the said tool is a fish gripper.

16. A device according to any preceding claim, wherein the inner and outer arms are each of stressed-skin construction.

17. A device according to any preceding claim, wherein a second arm is mounted on the support structure, the two arms being of similar construction.

18. A device accordig to claim 17 as dependent on claim 2 wherein the second arm is inverted relative to the first except for the workhead, the inner arms are rotatably mounted on the column at spaced positions and the two workheads are operative at the same level or range of levels.

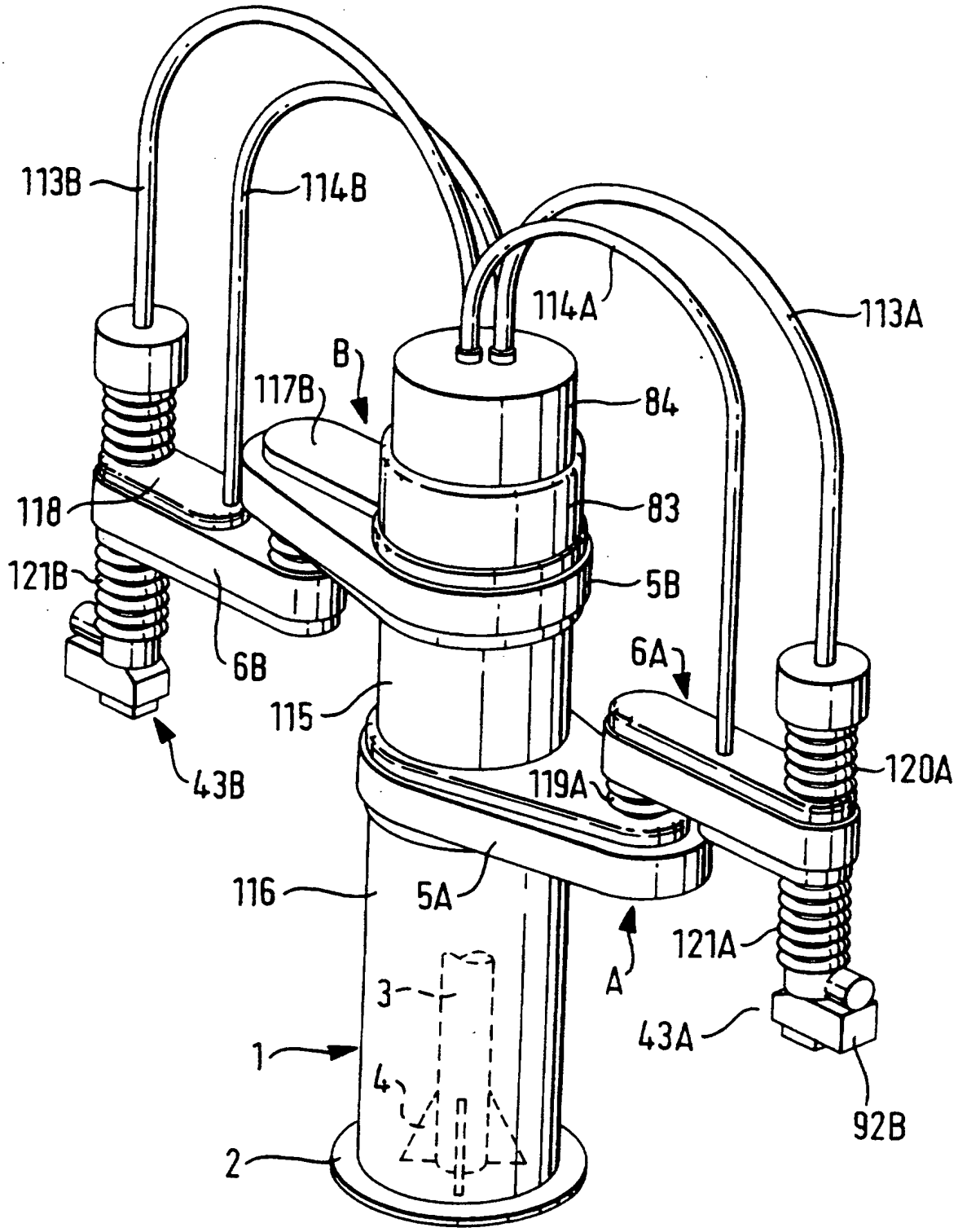
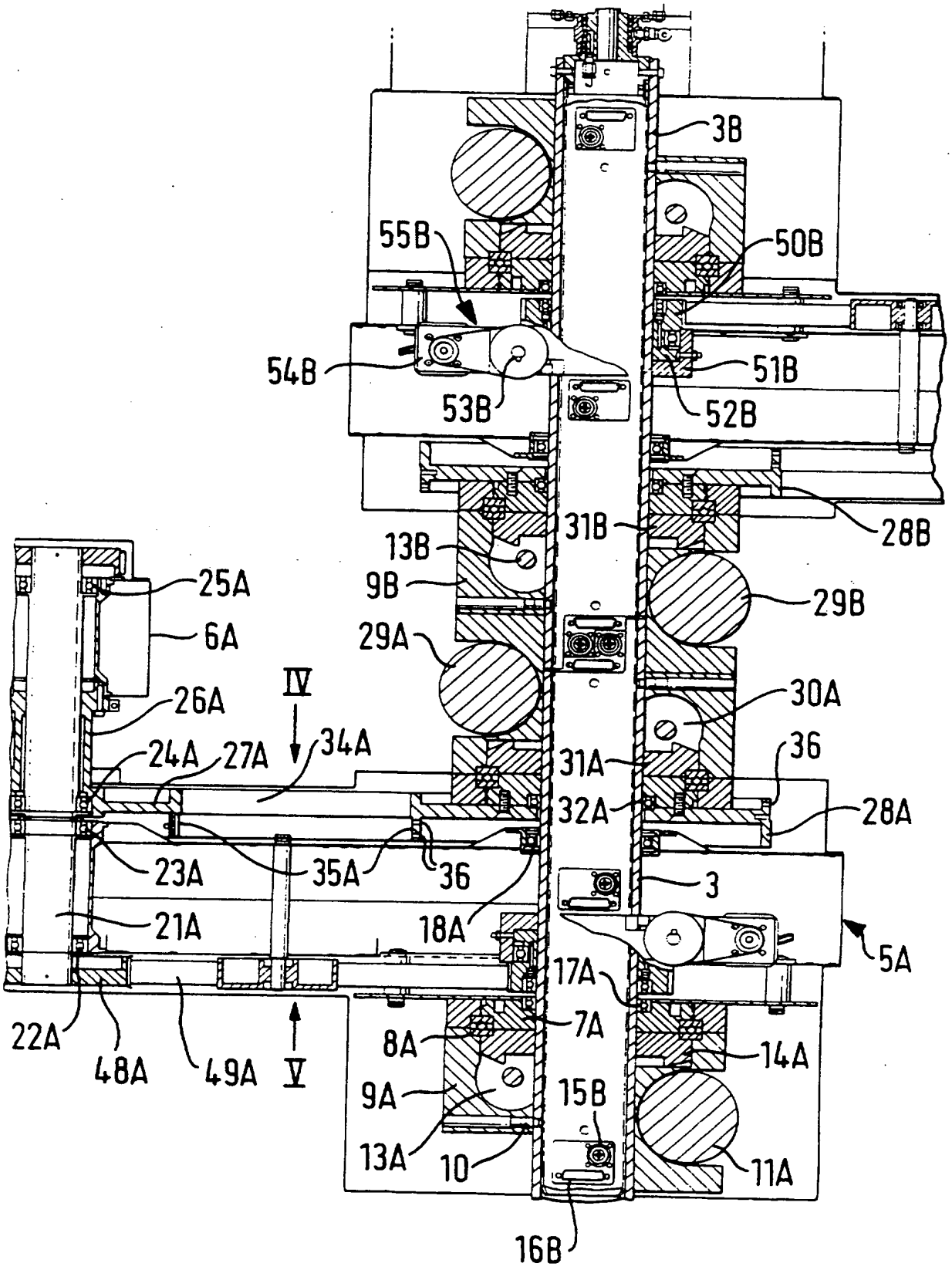


FIG. 1

FIG. 2



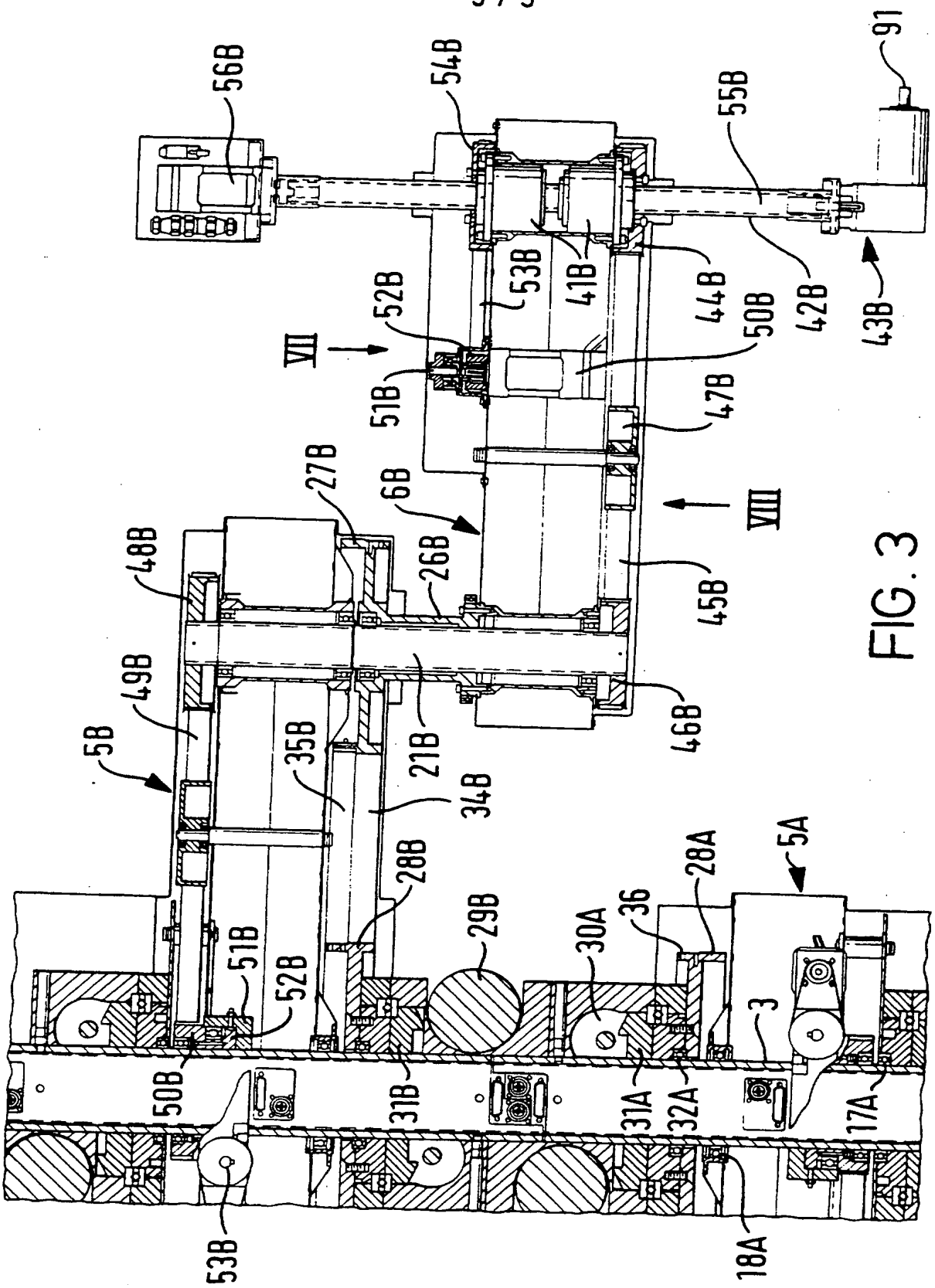


FIG. 3

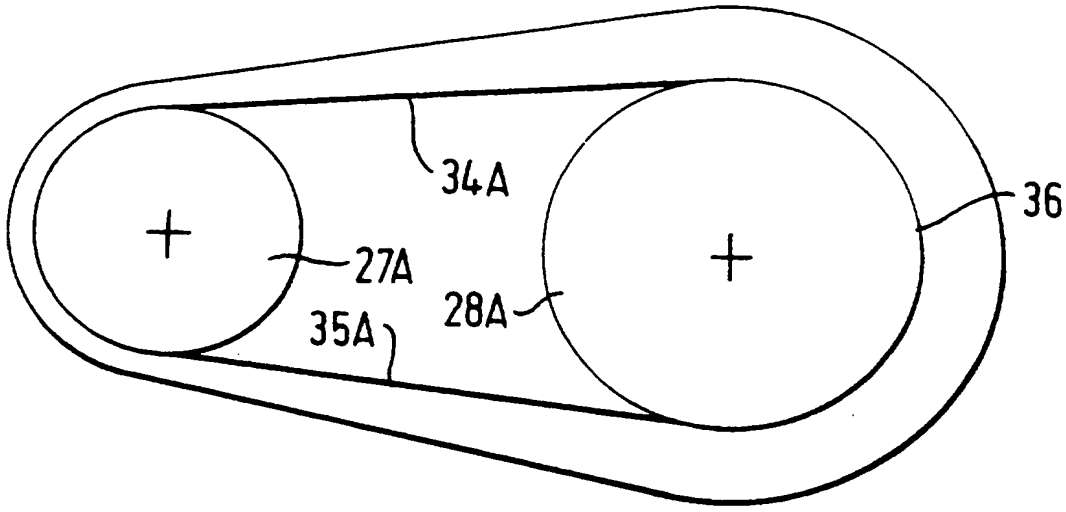


FIG. 4

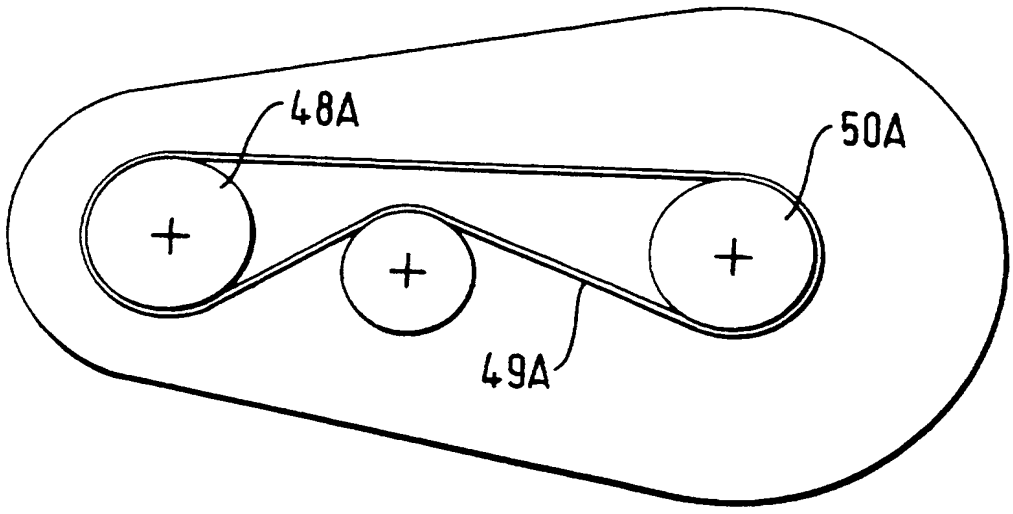


FIG. 5

FIG. 6

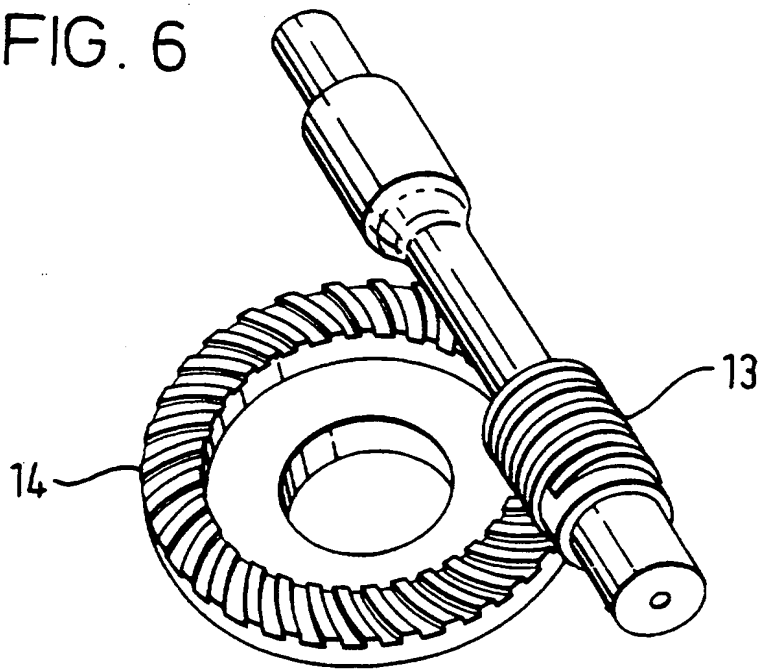


FIG. 7

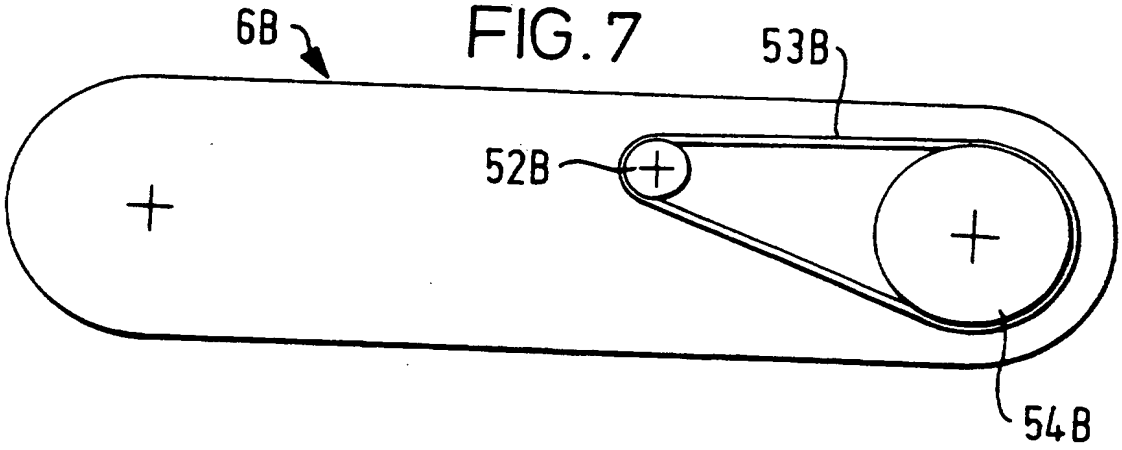
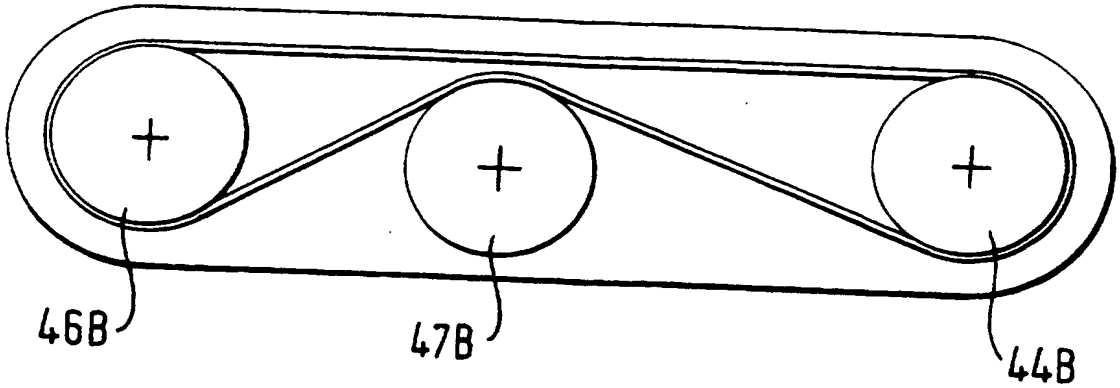


FIG. 8



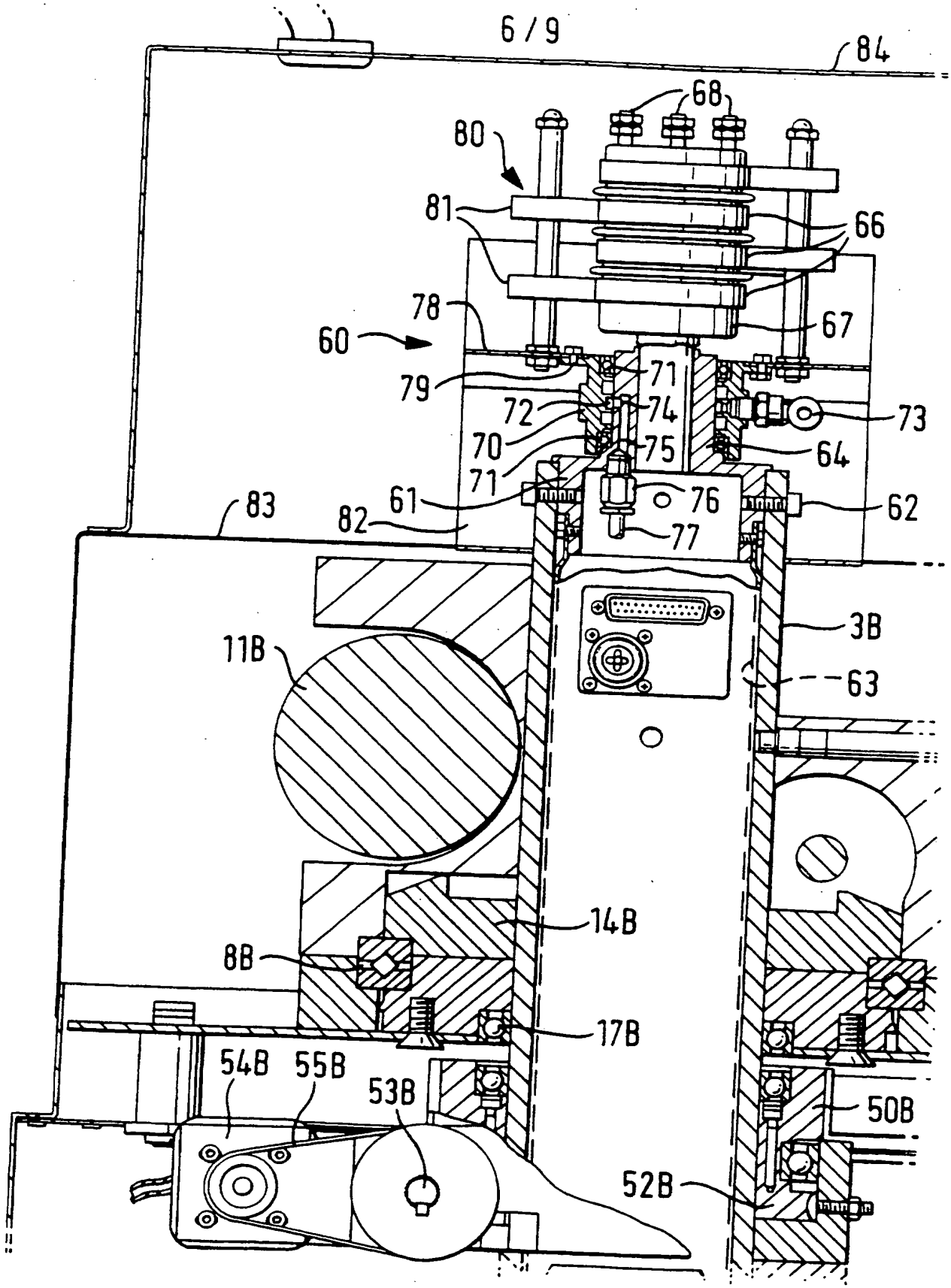


FIG. 9

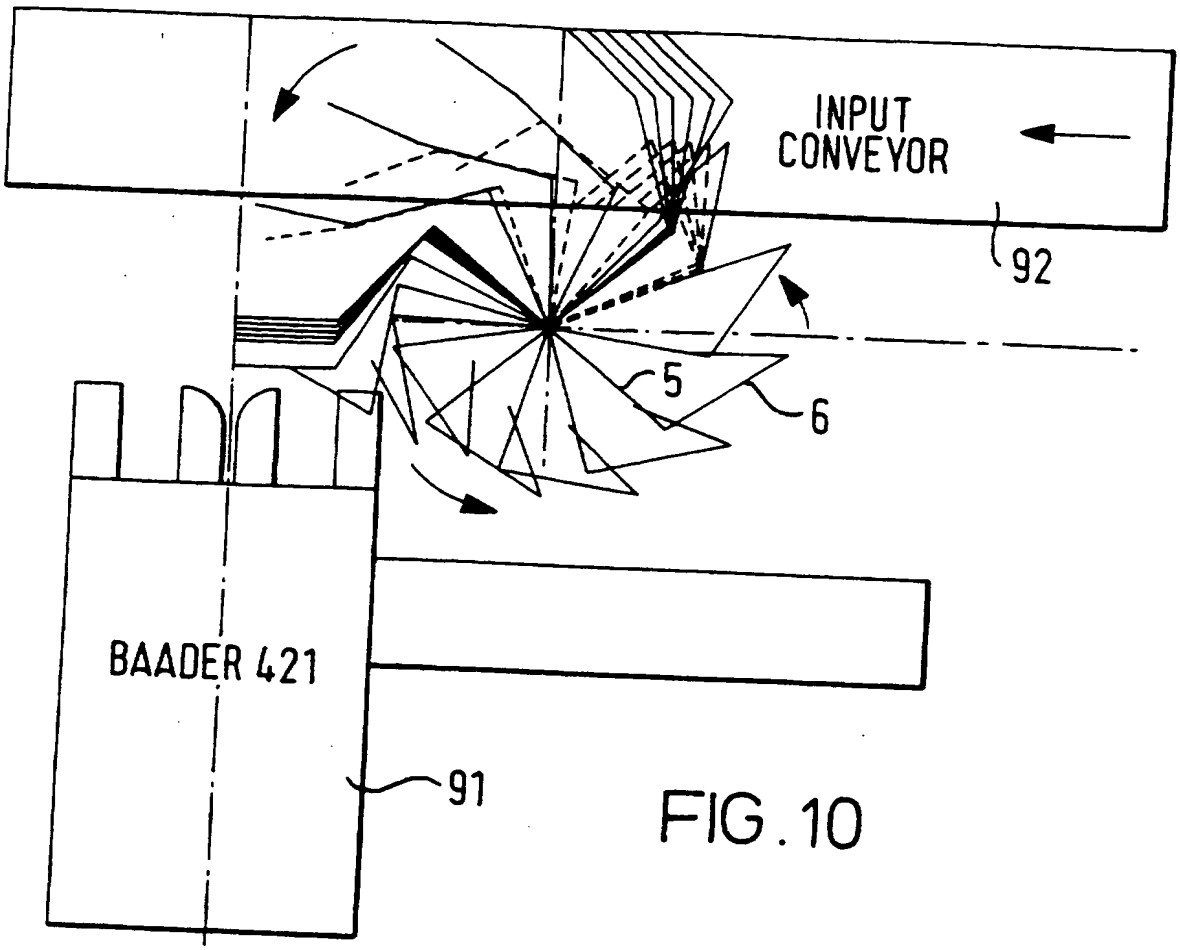


FIG. 10

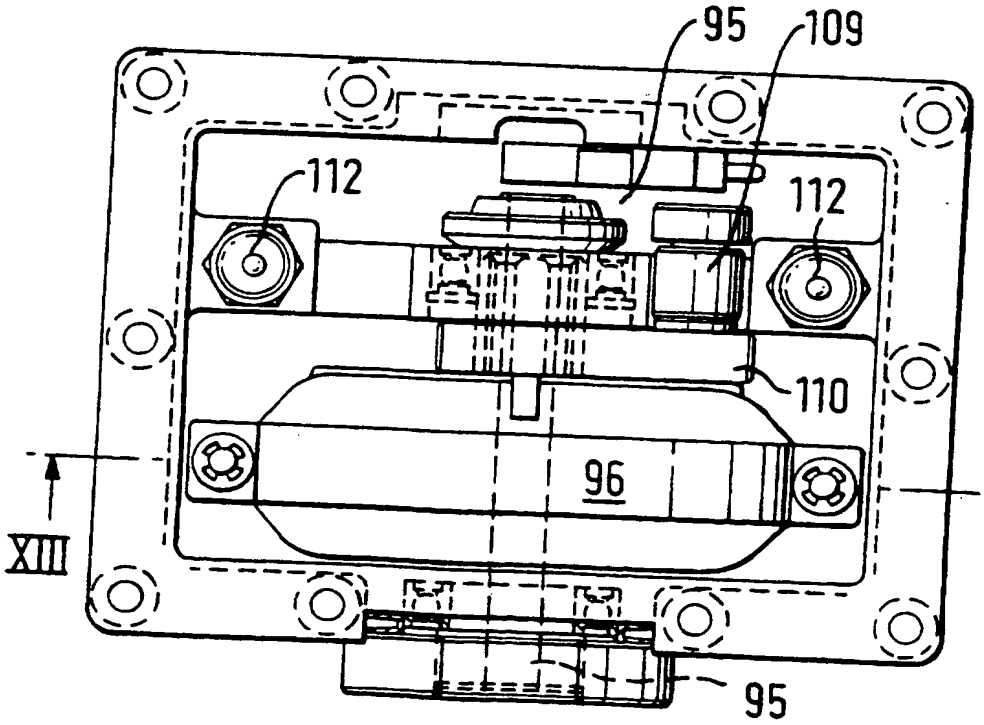


FIG.12

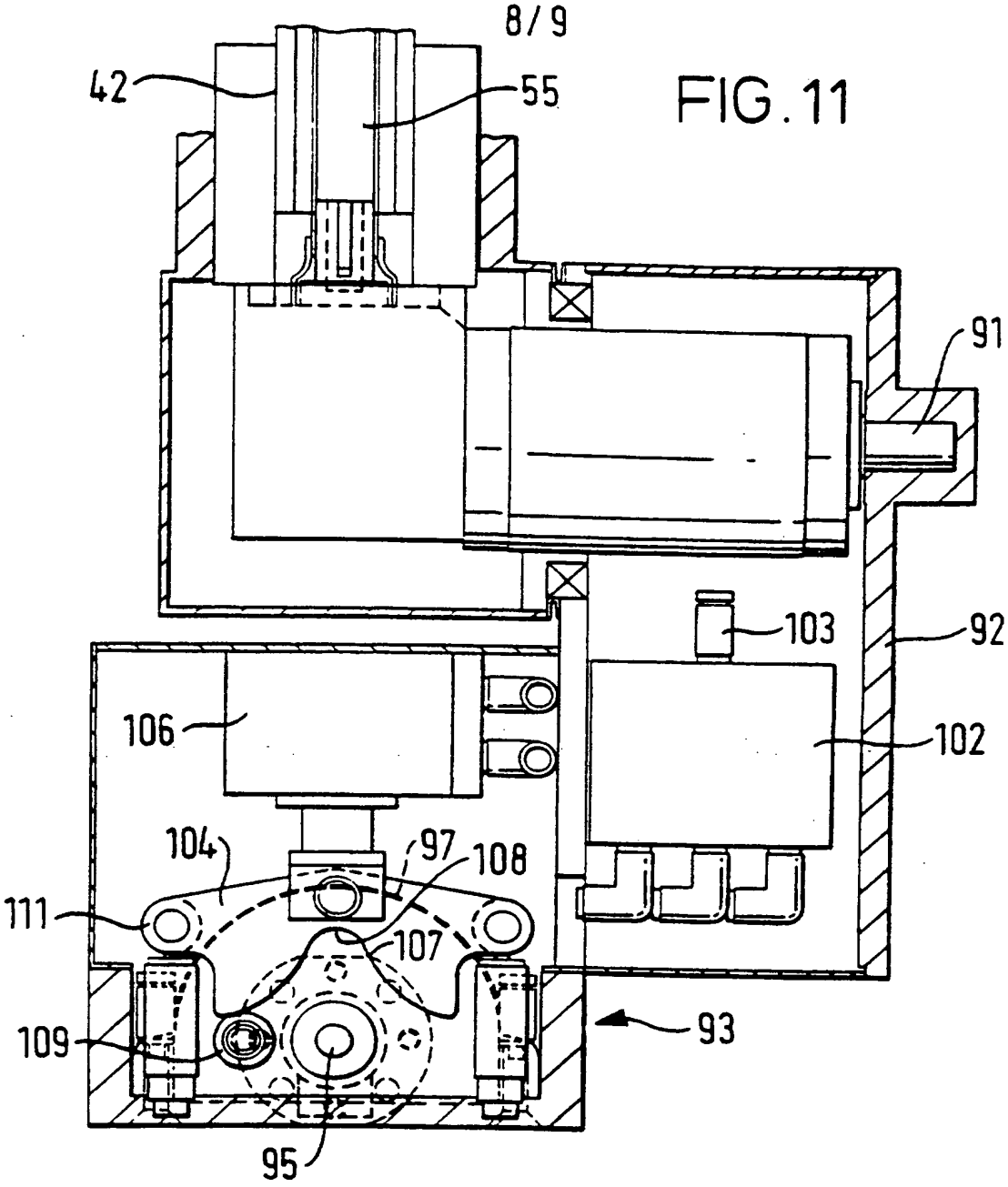


FIG. 11

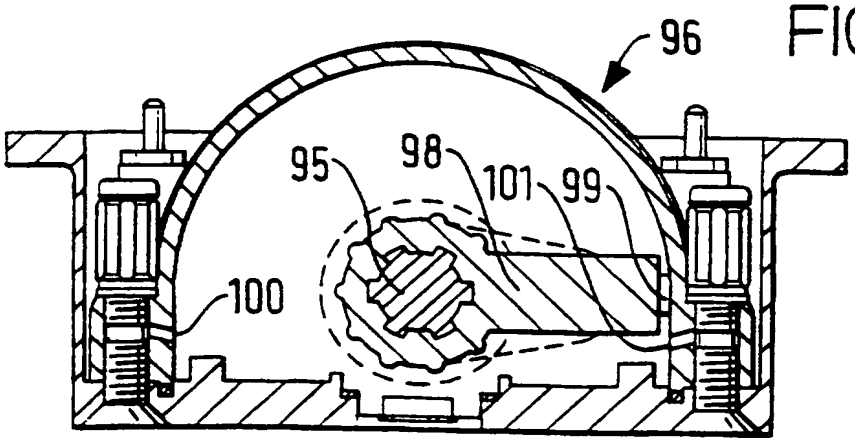


FIG. 13

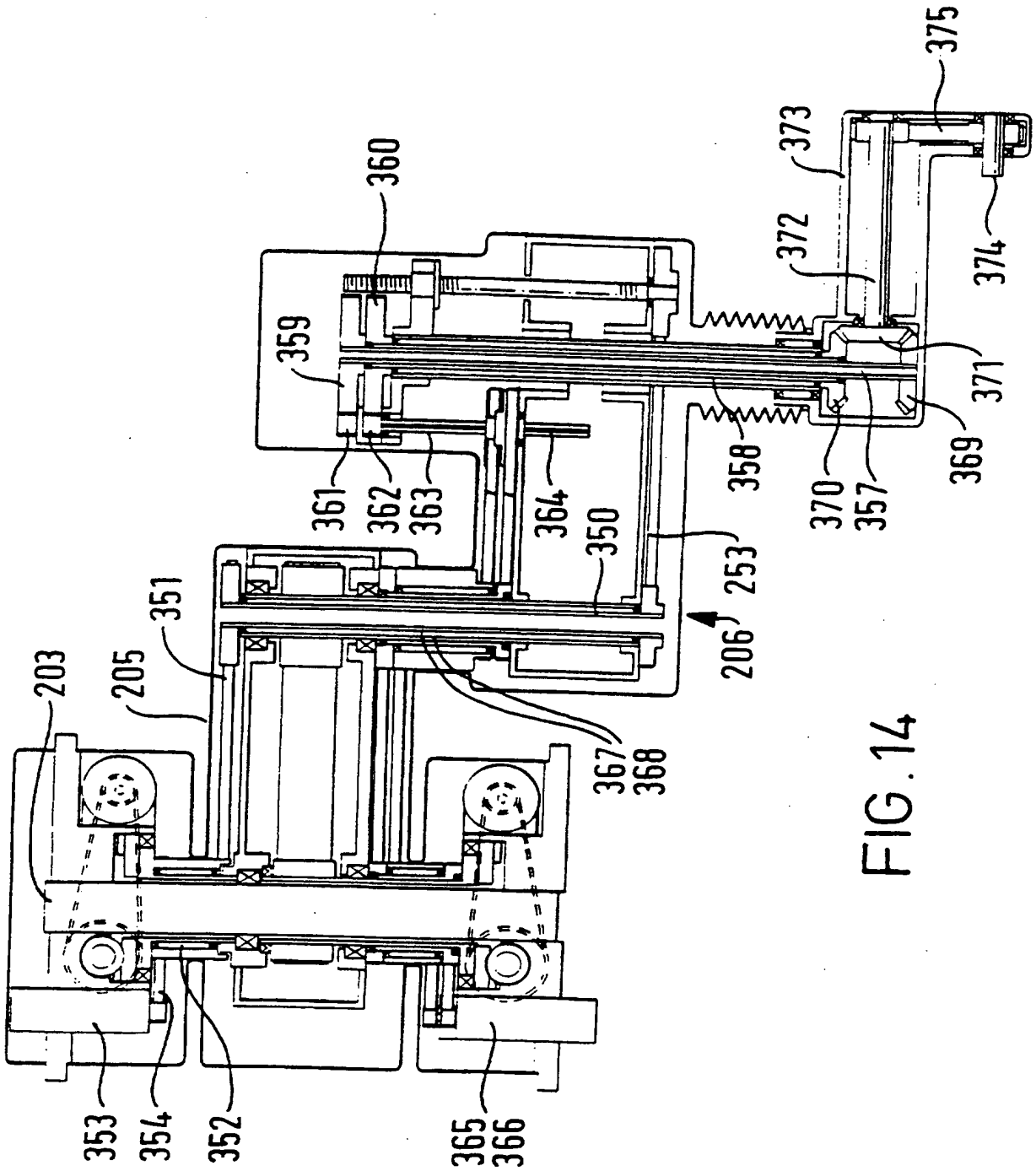


FIG. 14

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/GB 95/02199

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B25J9/04 B25J19/00 B25J9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B25J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP,A,0 188 863 (ADEPT TECHNOLOGY) 30 July 1986 see page 7, line 3 - page 9, line 27	1 2,10,11, 17
Y	EP,A,0 102 082 (HITACHI) 7 March 1984 see page 8, line 16 - line 24; claim 1	2
Y A	FR,A,2 510 023 (PHAREMME) 28 January 1983 see page 3, line 6 - page 4, line 31	10,11 7,8
Y	EP,A,0 380 206 (SONY) 1 August 1990 see abstract	17
A	US,A,5 271 292 (SAWADA) 21 December 1993 see column 4, line 27 - line 38	6

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
11 January 1996	22.01.96
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016	Authorized officer Lammineur, P

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INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/GB 95/02199

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int onal Application No
PCT/GB 95/02199

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